PhD Thesis Subject Proposal 2019

Laboratory & research team:

- Laboratoire Leprince-Ringuet, École polytechnique
- Médical (PEPITES project)

Title:

Development of an ultra-thin monitor for charged particle beams.

Thesis project:

The proposal outlined here is the subject of a declaration of invention and basic principles are not disclosed.

Proton therapy dose delivery requires a continuous and precise measurement of beam properties, intensity, position and profile. When crossing the monitor material thicknesses, the beam undergoes a dispersion that should lead to a maximum submillimeter lateral spreading at the patient to be tolerable. For monitors located a few meters upstream of the patient, this constraint leads to a material budget lower than 15-μm water equivalent thickness (WET).

The continuous presence of the monitor in the line also requires good resistance to radiation. Even if the intensities of the beams used in the medical field are relatively low (a few nA) the exposure time results in integrated doses of some 10^6 à 10^8 Gy per year.

The solution developed by the LLR team exploits the methods of thin films to build the active part of the detector, which is made of a pattern deposited on a thin membrane. The use of these techniques in the beam monitoring field is new and is expected to have many advantages: thinness (less than 10 µm WET) leading to minimal beam spreading; freedom on the pattern with which to sample the beam profile (strips, pads, etc.); sub-millimeter accuracy for beam profiles and positions; broad dynamic range, from hundreds of fA to hundreds of nA of beam intensities; good resistance to radiation damages; less prone to heating effects from beam interaction; etc. If the technique is relevant for the mid-energies, where it is competitive, nothing prevents from using it well above. This approach may hence have a range of applications that is well beyond the foreseen proton therapy framework.

The Arronax[1] center has expressed its interest for a 10 µm water-equivalent system to be operated for proton, deuteron and alpha beams in energy ranges 17-70 MeV, 8-17 MeV/u and 17 MeV/u for protons, deuterons and alphas, respectively, in the sub-pA to 10 nA beam intensity range. Achieving a working prototype responding to these constraints would demonstrate the viability of the approach and would constitute a generic proof of principle to a wide set of monitors based on the same principles.

---

[1] Accélérateur pour la Recherche en Radiochimie et Oncologie à Nantes Atlantique

The thesis project proposes to carry out a complete prototype (sensitive part and readout) to ascertain proof of principle of the approach and establish the performances of such a system. Studies will mainly rely on beam tests at Arronax facility and at least one test beam will occur at CPO (Centre de Protonthérapie d'Orsay), for protons from 70 to 230 MeV.

The candidate will work on the followings tasks:

- participation to beam tests with basic prototypes and study of the signal generation in targeted beam current and energy ranges
- comparison of merits by simulation between different patterns (strips, pads, etc.);
- study of radiation hardness, nuclear activation and thermal damages for various substrates and sensitives areas. These studies of irradiated samples will be done with the use of dedicated diagnosis apparatus to investigate microscopic damages and macroscopic changes of behavior (loss of mechanical resistance, alteration of electrical properties of the patterns, etc.). The results will lead to the choice of the material and technique for building the sensitive area of the final prototype;
- characterization of a low noise electronic readout system developed by our CEA partner. This study will occur when the final readout will be inserted on the final detector.
- with all elements put together, acquisition chain built and validated, the full prototype will be characterized in a last test beams and its performances established.

This work will assess in what extent thin film techniques are relevant to beam diagnostic. Several technical benefits are expected: small beam perturbation, applicability to a large range of beam currents and energies, lower thermal stress, etc. If these expectations are verified, the technique will be of great interest for medical charged particles accelerators, and would contribute to improve both proton and ions cancer therapies.

The subject constitutes a perfect multidisciplinary case. It is a particle physics spin-off, involving nanometer scale technologies, with foreseen application to the medical field. It will give the candidate the opportunity to work on a project with a time scale fitting the PhD grant duration.

Master and doctoral school:

- Master 2 in particle physics
- PHENIICS doctoral school – Université Paris-Saclay

Local team:

Medical applications group (resp. Marc VERDERI).

Contact:

Marc VERDERI verderi@in2p3.fr
Christophe THIEBAUX thiebaux@llr.in2p3.fr

PEPITES

PhD Thesis Subject Proposal 2019

université PARIS-SACLAY

Informations fournies pour la sélection du projet

- **Axe prioritaire de l'IDI 2019 retenu:**
  - « science et innovation »

- **Informations personnelles du directeur de thèse et co-encadrant :**
  - Directeur de thèse :
    - Marc VERDERI (responsable projet « PEPITES »)
    - verderi@in2p3.fr
    - Physicien (DR2)
    - Laboratoire Leprince-Ringuet (UMR 7638)
    - Employeur : CNRS
    - HDR : oui
  - Co-encadrant :
    - Christophe Thiébaux (directeur technique projet « PEPITES »)
    - thiebaux@llr.in2p3.fr
    - Physicien (CRCN)
    - Laboratoire Leprince-Ringuet (UMR 7638)
    - Employeur : CNRS
    - HDR : non

- **Titre du projet :**
  - FR : Développement d'un moniteur ultra-mince pour faisceaux de particules chargées
  - EN : Development of an ultra-thin monitor for charged particle beams

- **Résumé et mot clefs:**
  - Résumé:
    - FR:

Le suivi de dose délivrée proton thérapie nécessite un monitorage continu et précis de l'intensité, de la position et du profil du faisceau. Lors de la traversée des épaisseurs de matière du moniteur, le faisceau subit une dispersion qui doit conduire à une dispersion latérale inférieure à 1 mm au niveau de patient pour être tolérable. Pour un moniteur situé à quelques mètres en amont du patient, cette contrainte induit un budget matériel inférieur à 15 µm équivalent-eau. La présence continue du moniteur dans la ligne nécessite également une bonne tenue aux radiations.
La solution développée par l'équipe du LLR exploite des méthodes de couches minces pour réaliser la partie active du détecteur, constituée de motifs d'épaisseur nanométrique déposés sur des membranes minces. L'utilisation de ces techniques dans le domaine du monitorage de faisceau devrait avoir de nombreux avantages et conduire à des applications bien au-delà du domaine médical envisagé.
Le centre Arronax a exprimé son intérêt quant à un système de 10 µm en épaisseur équivalent-eau pour des faisceaux de protons, deutérons et alpha, avec des énergies inférieures à 70 MeV et des intensités dans la gamme sub-pA à 10 nA. La réalisation d'un prototype fonctionnel répondant à ces contraintes exigeantes démontrerait la viabilité de l'approche. C'est l'idée directrice du sujet proposé.
Le candidat participera aux tests en faisceau pour les études de génération de signal; comparera les mérites de différents motifs (bandes, pads, ...) par simulation; participera aux études de tenue aux

radiations et de dommages thermiques des membranes et de leurs motifs; à la caractérisation de l'électronique bas bruit sur le détecteur; et à la caractérisation finale du prototype complet.

Le sujet constitue un cas parfait de multidisciplinarité. C'est un spin-off de la physique des particules, impliquant des technologies de couches minces, avec une application prévue dans le domaine médical. Il donnera au candidat la possibilité de travailler sur un projet dont l'échelle de temps correspond à la durée de la bourse de doctorat.

- EN:

Proton therapy dose delivery requires a continuous and precise monitoring of beam intensity, position and profile. When crossing the monitor material thicknesses, the beam undergoes a dispersion that should lead to a lateral spreading below 1 mm at the patient to be tolerable. For monitors located a few meters upstream of the patient, this constraint leads to a material budget lower than 15-μm water equivalent thickness. The continuous presence of the monitor in the line also requires good resistance to radiation.

The solution developed by the LLR team exploits the methods of thin films with nanometer scale patterns deposited on thin membranes to build the active part of the detector. The use of these techniques in the beam monitoring field is expected to have many advantages and to lead to applications well beyond the medical field.

The Arronax center has expressed its interest for a 10 µm water equivalent thickness system for beams of proton, deuteron and alpha, with energies below 70 MeV and intensities in the sub-pA to 10 nA range. Achieving a working prototype addressing these demanding constraints would demonstrate the viability of the approach. This is the driving idea of the subject proposed.

The candidate will participate to beam tests for signal generation studies; compare merits of different patterns (strips, pads…) by simulation; participate to radiation hardness and thermal damages studies of membranes and their patterns; participate to low-noise electronic characterization on detector; and to characterization of the final prototype.

The subject constitutes a perfect multidisciplinary case. It is a particle physics spin-off, involving nanometer scale technologies, with foreseen application to the medical field. It will give the candidate the opportunity to work on a project with a time scale fitting the PhD grant duration.

- Mot clefs:
  - FR : Moniteur, faisceau, couches minces, proton-thérapie, hadronthérapie
  - EN : Monitor, beam, thin films, proton-therapy, hadrontherapy

- **Type de financement demandé:**
  - 100%

- **Unité de recherche soutenant le projet:**
  - Laboratoire Leprince-Ringuet
- **Ecole doctorale de rattachement :**
  - PHENIICS
- **Etablissement opérateur d'inscription :**
  - Ecole polytechnique
- **Etablissement employeur du doctorant :**
  - Ecole polytechnique